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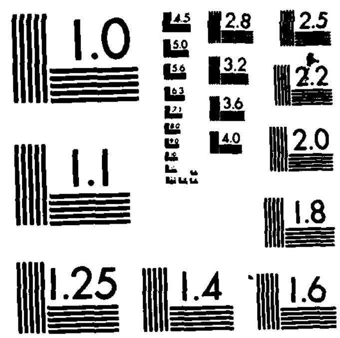
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AD-A160 077

FINAL REPORT

for the

OFFICE OF NAVAL RESEARCH

under

ONR N00014-79-C-0355

INTERACTION EFFECTS IN PREMIXED TURBULENT COMBUSTION

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University of California San Diego

In this final report we summarize the research carried out under the indicated contract during the period 1 March 1982 to 30 September 1985. This effort involved collabration with other workers: With Professor K.N.C.Bray, formerly of the University of Southampton and currently of Cambridge University, with Professor J.B.Moss, also formerly of the University of Southampton and currently of the Cranfield Institute of Technology and finally with Professor Forman A. Williams of Princeton University. In addition two doctoral students received their degrees at the University of California San Diego on the basis of research supported under this contract.

The research, involving collaboration with Professors Bray and Moss, has been concerned with two topics in premixed turbulent combustion. One relates to a continuation of the research, conducted for the Office of Naval Research under ~~the contract~~ preceding the one under consideration, namely ~~to~~ for the discovery of new mechanisms for turbulent transport and turbulence generation arising from the interaction of mean force fields due to gradients of either pressure or shear stresses and density variations. These earlier studies consider infinite planar flames and since the mechanisms in question are confined to the flames themselves, the question arises as to their applied significance and importance in determining global features of turbulent flows consisting of two regions of uniform density on each side of a flame. To examine this question we have extended the analysis to

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provide a unified theory for the description of all three regions; solutions of the equations given by this theory with the terms describing these mechanisms present and absent will permit an assessment of their importance, e.g.,in determining the orientation of the flame. Specialization of the general equations leads to new theories for normal and oblique flames and therefore to a means for assessing the validity of the general theory. A program for the systematic exploitation, asssesment and if needed, modification of these general equations has been set forth.

The second topic on which we have been collaborating with Professors Bray and Moss relates to the consideration of the length and time scales of the temperature field in a premixed turbulent flame. The time history of the temperature at a point within such a flame involves alternately high and low values corresponding respectively to the passage of products and reactants. By appropriate normalization such a history can be made into a telegraph signal whose statistical characteristics provide information on the time scales of the temperature field. We have shown that an analysis of these characteristics leads to a model for an important quantity in the phenomenology of premixed turbulent combustion, namely the mean rate of chemical reaction. Existing models therefor are of uncertain validity. One of the virtues of our analysis is that several intermediate steps in the development of the final model can be subject to comparison with experiments. In fact experimentalists working in premixed turbulent combustion have found our analysis to be useful in presenting and interpreting their temperature data. Further research along these lines in needed before a complete and fully validated model for the mean rate of chemical reaction is available.

With Professor Williams we have carried out several theoretical studies of the structure and characteristics of premixed laminar flames which are subjected to rates of strain. There are several motivations for such studies: the coordination of our theory with appropriate laboratory experiments on chemical systems of applied interest with flow conditions corresponding to our theory lead to the determination of overall chemical kinetic information which can be used in large scale computations. In addition the surfaces within which chemical reaction at a molecular level takes place in premixed turbulent flames are believed to be laminar flamelets and therefore to be described by our analysis. Our results apply to nonisenthalpic flames and to gas mixtures with Lewis numbers in the neighborhood of, but not equal to, unity; a range of rates of strain are treated. We show that under suitably high rates of strain no new products are created by the flamelet, i.e., extinction occurs. At the other extreme, i.e., low rates of strin the rate of creation of product

becomes identical with that for the classical unstrained laminar flame. This theoretical work will in due course be inteorated into a more complete theory for premixed turbulent flames. one in which the influence of a distribution of the rates of strain are taken into account. For example. related studies in nonpremixed flames indicate that a turbulent flame involving such intense turbulence that a large fraction of its flamelets are subjected to such high rates of strain that they are extinguished is itself likely to be extinguished. Similar considerations have not as yet been applied to premixed turbulent flames but our studies provide one of the essentail elements for such studies.

The following is a listing of the publications reporting the results of research under this contract:

Calender Year 1982:

Libby, P.A. and Williams, F.A., The structure of laminar flamelets in premixed turbulent flames. Combust. Flame 44, 287-303 (1982).

Bray, K.N.C., Moss, J.B. and Libby, P.A., Turbulent Transport in Premixed Flames, in Convective Transport and Instability Phenomena, Eds. J. Zierep and H. Oertel, G. Braun, Karlsruhe, 389-423 (1982).

Calender Year 1983:

Shepherd, I.G. and Moss, J.B., Characteristic scales for density fluctuations in a turbulent premixed flame. Combust. Sci. Tech. 33, 231-243 (1983).

Libby, P.A., Linan, A. and Williams, F.A., Strained premixed laminar flames with nonunity Lewis numbers, Combust. Sci Tech. 34, 257-293 (1983).

Calender year 1984:

Libby, P.A. and Williams, F.A., Strained premixed flames with two reaction zones, Combust. Sci. Tech. 37 221-252 (1984).

Champion, M. and Libby, P.A., Turbulent boundary layer with premixed combustion. Combust. Sci. Tech. 38 267-291 (1984).

Bray, K.N.C., Libby, P.A. and Moss, J.B., Flamelet crossing frequencies and mean reaction rates in premixed turbulent combustion. Combust. Sci. Tech. 41 143-172 (1984).

Bray, K.N.C., Libby, P.A. and Moss, J.B., Scalar lenoth scale variations in premixed turbulent flames. Twentieth Symposium (International) on Combustion. (accepted)(1984)

Moss, J.B., Light scatter turbulence measurements in thin-flame premixed combustion. Twentieth Joint Propulsion Conference AIAA/ASME, Cincinnati, June 11-13, 1984

Calendar Year 1985:

Libby, P.A., Theory of premixed turbulent flames revisited. Prog. Energy Combust. Sci. 11 83-96 (1985).

Bray, K.N.C., Champion, M., Dave, N. and Libby, P.A., On the thermochemistry of premixed turbulent combustion in variable enthalpy systems. Combust. Sci. Tech. 44 31- (1985).

Bray, K.N.C. and Libby, P.A., Passage times and crossing frequencies in premixed turbulent combustion. Combust. Sci. Tech. (accepted) (1985).

There are several manuscripts in various stages of completion describing work in progress.

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